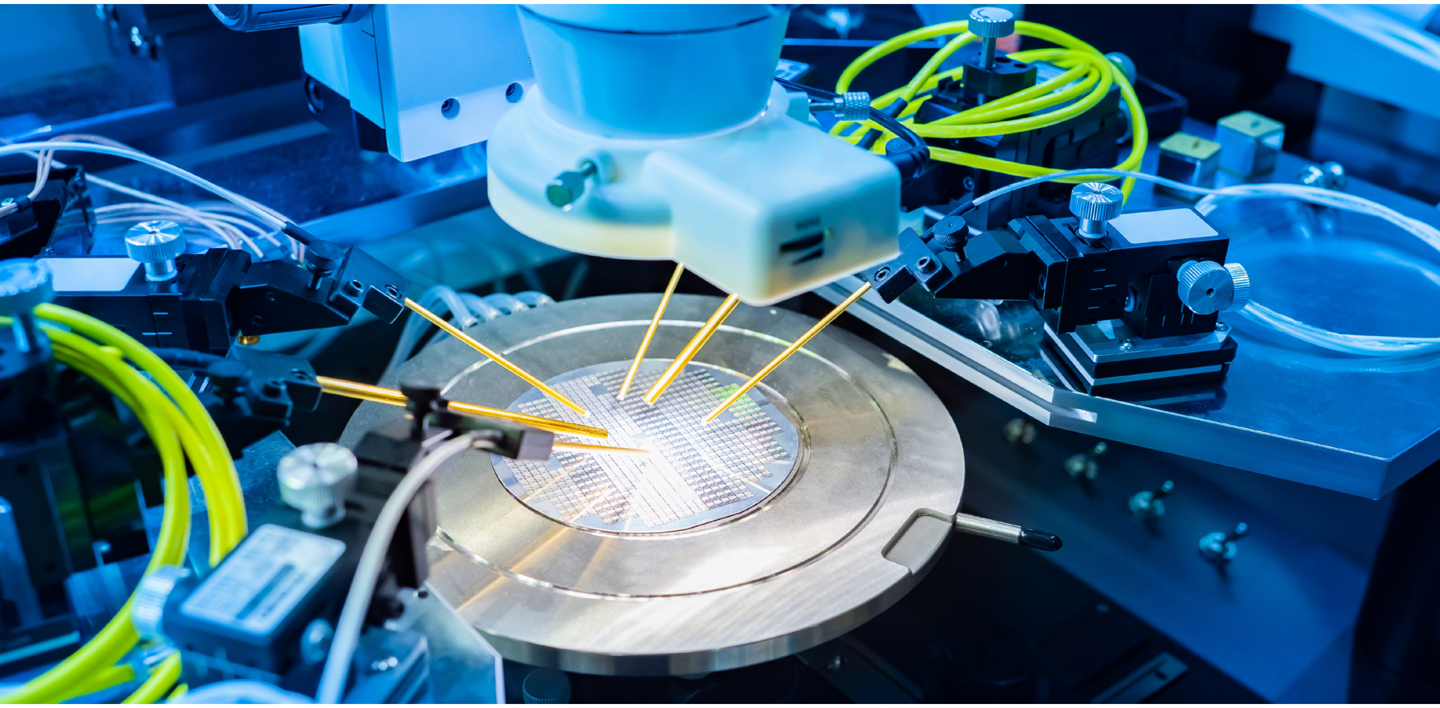
Application Guide

Relay Technology for High Power Switching Applications



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50 years 1968 - 2018

Selecting High Power Switching Technology

When designing equipment that requires the switching of high-power, it is important to choose components that will deliver the best performance. With high current levels or inductive loads (motors or solenoids, for example) or with capacitive or surge loads (power supplies or heating elements, for example), electromechanical relays or semiconductor switches are usually the best option. Often, it will be the only load the device switches and the number of required operations may be relatively low, less than 10,000. Choosing the right component is just a matter of ensuring its ratings exceed those of the load. As the load increases, larger, higher-rated components can be selected.

In these consistent load applications, there are few if any other considerations; the device simply needs to turn the load on and off. However, in other applications, there can be a range of loads and signals that need to be switched, leading to potential compromises when choosing an electromechanical relay or a semiconductor switch that can accommodate a variety of loads.

Reed relays are usually associated with low level applications, where their unique attributes provide performance advantages compared to other switching technologies. However, they are widely used in areas where higher power levels within their maximum ratings need to be switched or where the requirement is carry current, either continuous or pulsed. For example, in semiconductor testing there can be a wide range of signals with voltages from millivolts to kilovolts and with currents from picoamps to amps. The construction of a reed relay means it can accommodate all of these.

When carrying out qualification and final test on products ranging from components to complete systems, a selection of signals may need to be switched in and out of the device under test. If the loads to be switched are beyond the ratings of a reed relay, then the best choice will be an electromechanical relay or semiconductor option. However, if they are within the ratings, choosing an appropriate reed relay may not only equal the performance of other switching technologies, but it might also provide a better overall solution. Using a mix of switching technologies can ensure the most efficient set up, resulting in the best overall performance.

Certain applications might achieve optimal performance by utilizing a mixture of various relay technologies. The image above serves as an illustration of a module that incorporates both reed relays and EMRs.

This is something many users in a wide range of industries have discovered- from established applications like semiconductor and equipment testing to new ones such as use within the renewable energy sector, or space.

email: techsales@pickeringrelay.com

High Power Applications

Reed relay operating speeds can be 10 times faster than even a small electromechanical relay, greatly reducing cycle times, and with no mechanically operated moving parts, the mechanical life can be 1000 times longer. Because a reed relay's contacts are sealed in either an inert gas or a vacuum, the contact surfaces will not oxidize; where oxidation can seriously affect the ability of electromechanical relays to switch low levels. Indeed, many often specify a minimum switched current. This is not a concern for a reed relay, which is ideal for applications with a varied switching load.

Compared to semiconductor switches, the off-state leakage currents for a reed relay can be picoamps(pA) compared to microamps(mA) for a solid-state device, and the capacitance between the connections can be 100s of picofarads(pF) compared to a reed relay which can be lower than 1pF. For many semiconductor switches, the on resistance can be much higher when compared to either reed or electromechanical relays.

Furthermore, reed relays boast impressive standoff capabilities, reaching over 15kV, with even miniature parts withstanding up to 5kV. This far surpasses the limitations of both electromechanical relays and semiconductor switches, which can be limited to 1kV to 1.5kV.

Making the Move to Reed Relays

These advantages have helped users find superior alternatives to their existing switching technologies, particularly when seeking improvements in overall performance. For instance, in mixed-signal semiconductor testing, the high-voltage performance of reed relays has successfully addressed the limitations posed by solid-state relays, thereby enhancing testing capabilities in critical areas.

In military and aviation applications, after relying on specific electromechanical relays for many years, engineers have discovered the speed and long-life advantages that reed relays brought to their applications. Similarly, in data analysis applications where there is a requirement to switch both higher power control loads along with very low-level monitoring signals, having struggled with both electromechanical and solid state relays, engineers have discovered that high power reed relays can switch between tasks seamlessly, with no compromises.

Updating from Mercury Wet Relays

Another topic worth mentioning is the use of mercury wet relays. For many years these were the device of choice for many applications requiring low level and high-power switching. However, recent environmental concerns of any mercury-based technology have resulted in a decline in the use these relays; and responsible manufacturers no longer offer mercury wet relays for new designs and recommend customers seek alternatives where they are already used.

The unique selling point of mercury switches was the fact they produced zero bounce on operation, an important consideration in some applications many years ago, though it's less significant in today's context. Also, they generally had higher switching specifications compared to dry reed relays. However, with advances in reed switch plating technologies, this has resulted in the availability of reed relays with comparable, or even higher ratings than other similar sized switches.

Furthermore, whereas the contact resistance of a general reed switch 20-30 years ago was inferior to a mercury wet switch, this advancement in reed switch plating means an instrumentation-grade dry reed switch is not so different now. Indeed, a number of semiconductor companies who initially selected mercury devices when they designed their test equipment years ago have now moved over to instrumentation-grade dry reed relays with no loss in performance.

Life Expectancy

Defining what is low and what is high power, in terms of the load the switching device connects to, is virtually impossible. There are too many permutations of voltage and current, and the picture is further complicated by inductance and capacitance.

However, if considered from the perspective of wear on the switching device, it would be fair to say that a low power load will not, even over the course of millions of switching operations, cause any significant damage or stress to the switching device. The life expectancy of the device is therefore dependent on the wear of contacts in the case of electromechanical and reed relays and the electrical life of the semiconductor material in a solid-state switch.

For higher power, this would be a load that introduces some kind of damage or stress to the part during switching operation. In the case of electromechanical and reed relays, this could be arcing as contacts come together. In the case of a solid-state device, the damage could be substrate warping and delamination as a result of heat buildup or aggressive thermal cycling.

Irrespective of the switching method, as power increases, the life expectancy of the device will be reduced. What is an acceptable life expectancy in the application is up to the user to decide, as they need to consider things like total cost of ownership, for example. If the reduced life is not acceptable, an alternative device will need to be selected; one with a higher switch power rating.

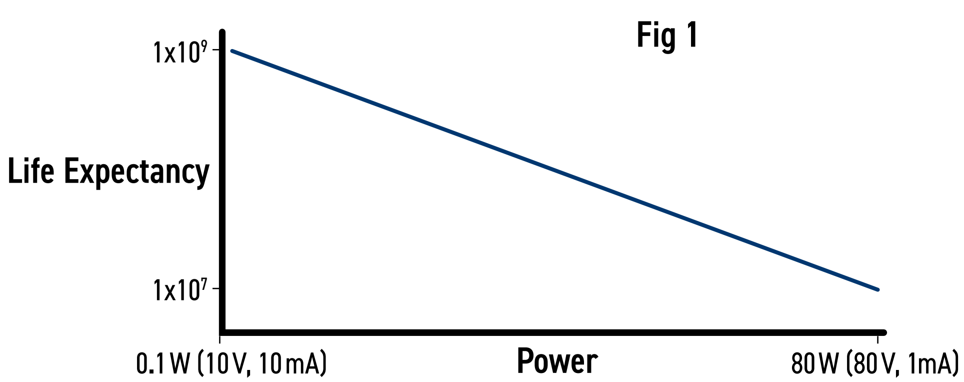


Fig 1 - Life expectancy graph of the Pickering Series 144, showing that as power increases, life expectancy decreases

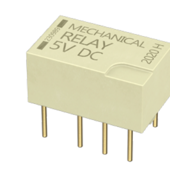
If using an alternative part is not possible - due to size restrictions or drive circuitry, for example – one option might be to modify the way the load is switched. If cold switching is an option, the life expectancy can be the same as would be expected for a low load application.

To help select which is the best switching technology, manufacturers typically provide ratings for all the important parameters, as well as life expectancy figures for low and medium loads, and at maximum ratings. These can serve as a guide to help select the most suitable switching device, but also give extra information that may be relevant to specific applications. For example (and with no particular switching technology in mind), switch path resistance, standoff voltage, insulation resistance, and operating factors such as coil current and gate/base drive voltages, all will influence performance.

Comparing Relay Technologies

There are essentially four ways to electronically switch a high power.

Electromechanical Relays (EMRs)



A popular and trusted technology capable of switching high power.

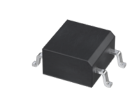
However, because the contacts are exposed to atmosphere a large contact gap (and therefore relay body) is needed to achieve higher standoff voltages where required.

Mercury Wetted Reed Relays

The contacts are protected from the atmosphere, so a high standoff voltage can be achieved in a smaller body than an EMR.

However, the use of mercury very often means the device must be precisely mounted (within a few degrees of vertical). Also, mercury is bad for the environment, and its use is being banned in many countries.

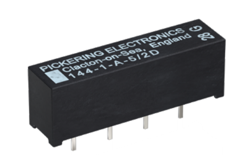
Solid State Relays (SSRs)



There are no physical contacts, as the switching elements are transistor-based.

However, the on resistance can be relatively high, meaning high power losses and thermal management challenges. Also, SSRs can fail in such a way that there is crossover between the control and switching sides of the device.

Reed Relays



The contacts are protected in a vacuum or inert gas, so a high standoff voltage can be achieved in a small package; unlike an EMR. Reed relays are now available with power ratings similar to mercury wetted reed relays, but which can be mounted in any orientation. Also, they have a low on-resistance and good isolation between control and switching sides; unlike SSRs.

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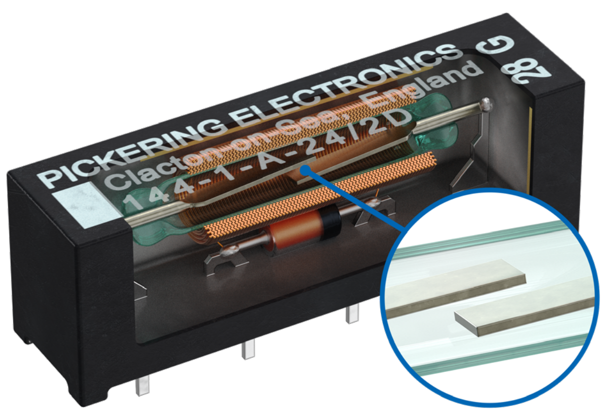
When choosing a reed relay for a semiconductor test application, the following are the most crucial factors to consider:

- **Maximum Switching Voltage.** The highest DC or AC (peak) voltage that can be switched.
- **Minimum Standoff Voltage.** The minimum DC or AC (peak) voltage that the device can standoff. An important parameter for high voltage devices and in the case of Pickering Electronics' high voltage relays, for security they are tested at 500V above the declared standoff. For your design purposes we recommend you do not exceed the standoff voltage given on the datasheet.
- **Maximum Switching Current.** Most reed relays are rated at up to 0.5A, but some smaller higher power devices are rated to switch up to 2A and larger devices up to 3A.
- **Maximum Carry Current.** The maximum continuous current that can be carried by the device when the switch is closed. This can be increased where the carry current is pulsed, the value dependant on the duty cycle.
- **Insulation Resistance.** This is the resistance between any of the device pins. This needs to be very high (ideally greater than 1TΩ (Tera Ohms, so 1 x 10^{12} Ohms) if the reed relay is to be used in circuitry intended to measure insulation resistance. Or, to put it another way, if you are trying to measure a current leak (indicative of failing insulation), the last thing you want is for your switching circuit to introduce a current leak, which is why solid-state relays are considered unsuitable.
- **Magnetic Screening.** Switch contacts in a reed relay are operated by the magnetic field generated by a coil. When stacked closely, adjacent relays will partially oppose each other's magnetic field causing magnetic interaction, which reduces the sensitivity of the switch and can increase the voltage needed to operate. To avoid this, magnetic screening can be utlilized to concentrate the magnetic field, greatly reducing the magnetic interaction. This allows for a higher packing density, especially with magnetic screening that covers both sides of the switch. Steel can be used, but Pickering recommends mu-metal magnetic screening because of its high permeability and very low magnetic remanence.



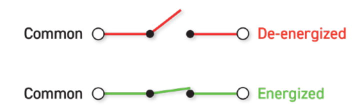
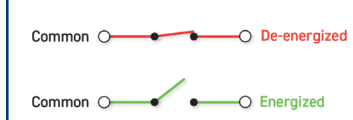
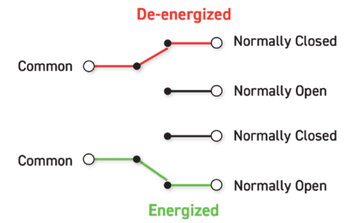
For reed relays, the contact can be sealed in a vacuum, greatly increasing the minimum standoff and maximum switching voltages. Insulation resistance is high thanks to pin spacing and the relay's base material. As for external shield clearance, this is not an issue when the EM shielding is on the inside of the device.

Other information you will need to consider when designing your monitoring circuitry includes:

• **Coil Voltage.** The DC voltage needed to energise the coil and close the normally open contacts in the reed.

• **Coil Resistance.** If energising the coil using a transistor, you need to know the coil resistance to calculate the current the transistor must handle.

Contact Configuration (Forms)

Form A	Form B	Form C
		
With the coil de-energized the switch is normally open (NO). If just one switch is present, the form is 1A, meaning single pole single throw normally open (SPST-NO). If two switches are present, the form is 2A, meaning double pole single throw normally open (DPST-NO). With three switches it is 3A (3PST-NO).	With the coil de-energized the switch is normally closed (NC). If just one switch is present, the form is 1B, meaning single pole single throw normally closed (SPST-NC). If two switches are present, the form is 2B, meaning double pole single throw normally closed (DPST-NC). With three switches it is 3B (3PST-NC).	These are changeover devices that break their NC contact (and close the NO one) when the coil is energized. If just one switch is present, the form is 1C, meaning single pole, double throw (SPDT). If two switches are present, the form is 2C DPDT. With three switches it is 3C.

What's the Service Life?

This is the one figure on any datasheet, from any manufacturer, that is open to interpretation. We state 1 x 10^9 operations for most applications, but the fact of the matter is the figure could be higher or lower depending on the exact application. Considerations are: How close to voltage and current limits are you operating? What is the switching duty cycle? Are you likely to see inrush currents?

Also, at what point do you consider the device to be failing? When contact resistance increases by 10%? 20%? More?

For more information on life expectancy, check out our article at:
https://www.pickeringrelay.com/reed-relay-life-expectancy/

Rest Assured, We're Here to Help

Tell us about your application and we'll not only recommend the most suitable device, but we'll also give you an indication of the device's realistic service life.

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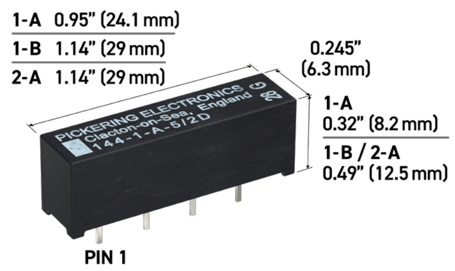
RECOMMENDED PRODUCTS

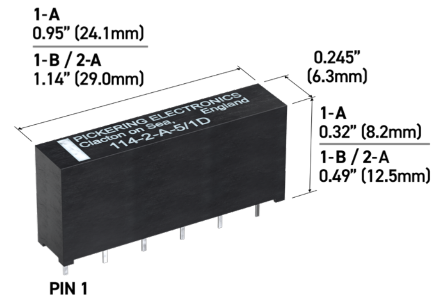
Pickering Electronics has an extensive range of high-performance, high voltage isolation reed relays that are ideally suited to high voltage switching applications. Furthermore, with device footprints starting at just 16mm², many relays can be accommodated on a single PCB. We particularly recommend the following series.

Series 144 - Up to 80W



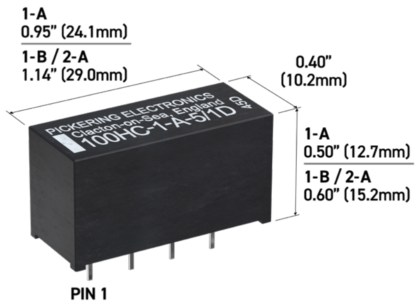
The **144** relays boast a power rating up to **80W** with switch current of up to **2A**, and the maximum carry current is **3A**. Can replace mercury wet reed or miniature EMRs. Additionally, they're suitable for high voltage applications with a maximum switching voltage of **1kV** up to **10W** and the option of **2kV** or **3kV** standoff.
Available forms:
1 Form A, 2 Form A, and **1 Form B** contact configurations.

Series 114 - Up to 40W



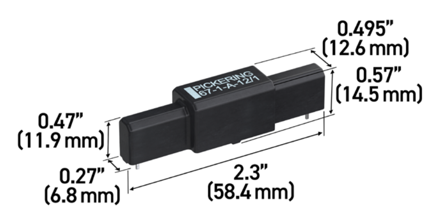
The **114** relays have a power rating up to **40W** with switch current of **1A**, and the maximum carry current is **3A**. Switches feature sputtered ruthenium contacts suitable for low level or dry switching. They switch AC mains voltages, making them ideal for interfacing with larger electromechanical relays.
Available forms:
1 Form A, 2 Form A, and **1 Form B** contact configurations.

Series 100HC - Up to 40W



The **100HC** relays have a power rating up to **40W**, maximum switch current is **1A**, and **3A** continuous carry current with even higher levels in pulsed current applications. High coil resistance of up to **6000Ω** for low power consumption. Thermal EMF levels less than **10μV**
Available forms:
1 Form A, 2 Form A, and **1 Form B** contact configurations.

Series 67 - Up to 200W

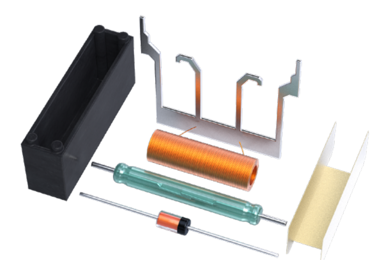


These Series **67** relays feature the highest power switch in the Pickering portfolio with a power rating up to **200W**. Switch current is **3A**, and the maximum carry current is up to **5A**. They are also suitable for high voltage applications with a stand-off voltage of up to **8kV**, and capable of **6kV** switching.
Available forms:
1 Form A and **1 Form C** contact configurations.

Why Pickering Electronics for Reed Relays?

- ✓ We've been making reed relays since 1968. It's our core business and has laid the foundation for the switching and simulation division of Pickering Group, **Pickering Interfaces**.
- ✓ The relays recommended in this guide are all instrumentation grade and the reed contacts will be plated with either Rhodium (electro-plated) or Ruthenium (vacuum spluttered) to ensure a long life – typically up to $5x10^9$ operations.
- ✓ They are of a **formerless coil construction**, which increases the coil winding volume, maximizes the magnetic efficiency, and allows for the use of less sensitive reed switches, resulting in optimal switching action and **extended lifetime** at operational extremes.
- ✓ Internal mu-metal magnetic screening enables **ultra-high PCB side-by-side packing densities** with minimal magnetic interaction, **saving significant cost and space**. Our magnetic screen reduces EM interaction to approximately 5%. Low quality relays typically exhibit an EM interaction of 30%.
- ✓ ***SoftCenter™*** technology provides maximum cushioned protection of the reed switch, minimizing internal lifetime stresses and **extending the working life and contact stability**.
- ✓ Inspection at every stage of manufacturing **maintaining high levels of quality**. Also, **100% testing** for all operating parameters including dynamic contact wave-shape analysis with full data scrutiny to maintain consistency. Stress testing of the manufacturing processes, from -20°C to +85°C to -20°C, repeated 3 times.

Customization
While we have recommended a variety of our high power relays, each with performance characteristics and properties that make them ideal for a wide rankge of applications where high power switching is required, we have over a thousand catalogue parts; so, there are plenty to choose from.



However, if you cannot find a product that meets your exact requirements, we offer a full customization service.

The series of devices recommended above already boast higher switching and carry currents and high insulation resistances, and those using vacuum reed switches have higher switching and standoff voltages, and these can all be increased in a custom design.

We have a well-proven development lifecycle of: Agree requirements, design, manufacture, test, approve, and deliver. And if your custom design is based on one of our existing products (which is likely to be the case) you can expect to receive samples in as few as two weeks.

For further information, contact our technical sales team at:
techsales@pickeringrelay.com

About Pickering Electronics

Pickering Electronics was established over 50 years ago to design and manufacture high quality reed relays, intended principally for use in instrumentation and test equipment. Today, Pickering's Single-in-Line package (SIL/SIP) range is by far the most developed in the relay industry, with devices 25% the size of our competitors' electrically equivalent devices. These small SIL/SIP reed relays are sold in high volumes to large ATE and semiconductor companies throughout the world.

The privately-owned Pickering Group comprises three electronics manufacturers: reed relay company Pickering Electronics; Pickering Interfaces, designers and manufacturers of modular signal switching and simulation products, and Pickering Connect, which designs and manufactures cables and connectors. The group employs over 500 people primarily in the UK and Czech Republic with additional employees in sales offices in the US, China, Germany, Sweden, and France.

Technical Help

Please go to: **pickeringrelay.com/help**.
If your questions are not answered here, please e-mail: **techsales@pickeringrelay.com**.
Alternatively, please call our Technical Sales Office on **+44 (0)1255 428141**.

Pickering Electronics Ltd.
Stephenson Road
Clacton-on-Sea
CO15 4NL
United Kingdom

Tel: +44 1255 428141
email: techsales@pickeringrelay.com
Web: pickeringrelay.com

Registered in England no. 857509 VAT no GB103 5366 04
Registered Office: Stephenson Rd, Clacton-on-Sea, Essex. CO15 4NL